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Method for pre treatment verification in Radiation Therapy

TECHNICAL FIELD

The present invention relates generally to radiation therapy treatment verification. In particular the invention pertains to methods, a detector configurations and a computer readable medium for verifying that a patient specific cancer treatment using radiation therapy, and in particular intensity modulated radiation therapy, is delivered as planned.

BACKGROUND OF THE INVENTION

Radiotherapy has been used to treat cancer in the human body since early 1900. Even though radiation of cancer tumours is known to be efficient, mortality rate for many cancers remained virtually unchanged for a long time. The major reasons for this have been the inability to control the primary tumour or the occurrence of metastases. Only by improving the local control may the treatment be more effective.
In the last years Treatment Planning Systems, TPS, in Radiation Therapy have developed extensively and is now able to take into account the anatomy of the specific patient and in a time efficient way plan a more optimised treatment for each individual patient, homogenous dose to the target and minimum dose to risk-organs.

The treatment technique to deliver this optimised treatment is more complicated than conventional treatments because each field must be modulated laterally in intensity and thereby compensate for the patients contour and anatomic heterogeneity, the technique is called IMRT – Intensity Modulated Radiation Therapy. The delivery can be done using compensators, filters individually made for each projection, that reduce the intensity to a predefined level in each part of the field due to attenuation of the primary photon beam. However when using several projections (4-8), each projection requiring individual

compensators, this technique is time-consuming and requires a lot of effort. Additionally the attenuation of the beam in the filter causes unwanted change of the beams spectral distribution, thereby complicating the whole process. The most common way to deliver IMRT is therefore using the MLC (Multi Leaf Collimator) a device that consists of thin blocks (collimator-leafs) that can be individually positioned to block a small part of the field and thereby shape the beam in the lateral direction to various irregular shapes. In each projection the collimator-leafs are moved during the treatment and thereby various part of the cross-section of the beam is irradiated during various times - the dose distribution is modulated. The conformity of the dose distribution to the tumour can be further improved using even more sophisticated techniques also changing the projection while the beam is on e.g. ARC-therapy.

In conventional therapy it is sufficient to make periodic verification on the level of the dose distribution on the central axis and in a few points off-axis to verify the beam-symmetry and beam-flatness. The new treatment technique is complicated and involves the transfer of information between several systems and therapy system sub-modules, and the cross section of the beam is individual for each projection on each patient, thereby extended quality assurance is required.

The fundamental of IMRT, building-up the dose in the field by blocking some parts of it longer than other often increases the beam-on time, and thereby the dose to the area outside the field increases. In IMRT accurate measurement of the dose to the areas outside the field is thereby more important than in conventional treatment, a requirement that further increases the demands in the measurement process.

Good quality control procedures in a radiation therapy clinic treating with IMRT technique includes:

- Machine specific quality assurance e.g. stability check of the dose rate, time for the treatment system to stabilise, mechanical QA of the MLC etc. before the treatment machine is accepted to be used for treatments.
- Pre treatment verification - Measurement performed on each individual treatment plan, before the patient is given the first treatment fraction, to verify the ability to deliver the treatment accurately.
- Patient dosimetry or in vivo dosimetry - Verification of the delivered dose to the patient during the actual treatment, see the Swedish patent application 0201371-2.

Pre treatment verification can be done for each individual projection using a 2D detector in a flat phantom positioned perpendicular to the beam or it can be done for one treatment occasion including all projections using a body phantom with detectors. Both methods have implementations using traditional measurement techniques and both of them have important limitations both in methodology and in measurement accuracy.

The shortcoming of the first method is:

- Complicated and time-consuming to verify each projection individually rather than the total contribution from all projections in one comparison.
- Unnecessary efforts invested in correcting minor errors per projection that would have shown to be neglectable if all projections could be totalised.
- The verification excludes errors in gantry angle and collimator rotation since the device is either attached to the gantry or the gantry rotation is not used during verification.
- It is not useful in ARC-therapy (described above).

The first method has been implemented in a product, MapCheck available from Sun Nuclear INC. , consisting of a matrix of detectors where each detector integrates the dose during the delivery of one projection. Measuring at one depth in the same beam direction simplifies most of the requirements on the detector to similar as in traditional measurements. However the requirement to measure with high accuracy outside the primary field, described above, raises several demands on the detectors and one of the hardest to fulfil for semiconductors is energy independency.

The second method simulates the patient on the couch using a body shaped or head-and-neck shaped plastic-phantom, see US-6,364,529 [MED TEC IOWA INC (US)), with some kind of detectors inserted into it. The phantom that is placed on the couch, without connection to the gantry rotation, can be irradiated similar to a patient in any relevant projection. Thereby the delivered dose from all projections can be measurement in any point inside the phantom. Error in delivery e.g. in MLC position, gantry angle, collimator rotation etc. will cause similar dose discrepancy in the phantom as in the patient.
Until now this method has been used with radiological films placed inside the phantom in the direction of the beam and a few point-detectors. The film measures thereby in 2-dimension (2D) along the beam with high spatial resolution. However, across the field, where the beam is modulated, the method is limited to measure along the film (1D). The main reason for the orientation of the film is the shortcoming of film as a detector. The response of radiological films depends on several parameters e.g. direction of radiation, energy, pressure (the pressure on the film at exposure), development process, fading, linearity etc. Additionally, film is an integrating detector and thereby the film-data has no time resolution and thereby analyses of the cause of a deviation between measurement and the treatment plan often become more or less impossible. Ideal point detectors would measure the point-

dose accurately, however a few point detectors will not enable verification of the intensity modulated beam in the various projections.

Ideal detectors do not exist and the current use measuring without synchronisation or documentation to the treatment phase and thereby the lack of time resolution makes it impossible to apply relevant corrections and thereby improve the result.

BRIEF DESCRIPTION OF THE INVENTION

Thus, an object of the present invention is to provide an efficient pre-treatment measurement method that sufficiently and accurately verifies the dose distribution from a complete treatment fraction (all beam projections) to be delivered to a patient.

Another subject of the present invention is to provide tools to find the causes of deviations compared to a treatment plan.

These and other objects are achieved according to the present invention by providing methods, a computer readable medium, and a detector configuration having the features defined in the independent claims. Preferable embodiments of the invention are characterised by the dependent claims.

According to a first aspect of the present invention, there is provided a method of measuring dose distribution in a phantom for radiation therapy treatment verification. The inventive method comprises the steps of: arranging at least two detector planes in said phantom in a non-parallel manner, each plane being provided with a plurality of detectors; irradiating said phantom using a patient specific treatment; obtaining information regarding the dose distribution inside said phantom by performing measurements using said detectors, wherein said information is to be used in the treatment verification.

According to a second aspect of the present invention, there is provided a method of configuration detectors in a phantom at measurements for radiation therapy treatment verification. The method according to the second aspect of the invention comprises the step of arranging at least two detector planes in said phantom in a non-parallel manner, each plane being provided with a plurality of detectors.

According to a third aspect of the present invention, there is provided a detector configuration in a phantom suitable for radiation therapy treatment verification characterised by at least two detector planes provided with a plurality of detectors for measuring irradiation in the phantom, wherein said planes is arranged in a non-parallel manner.

According to a further aspect of the invention, there is provided a computer readable medium comprising instructions for bringing a computer to perform the method according to the first aspect of the invention.

Thus, the invention is based on the idea of a configuration of detectors in two or more non-parallel planes in a phantom e.g. body-phantom (without connection to the gantry rotation, i.e. the rotation of the device applying the irradation). The special configuration of the detectors makes it possible to verify the intensity modulation across the beam in any beam projection and at the same time totalise the dose from all projections in the fixed measurement-points in the phantom. Obviously, this is a clear advantage of the present invention compared to existing solutions. For example, a placement of the detectors in a 3D matrix would require an extensively increased number of detectors, which, in turn, would entail very highs costs and which also would require significant processing times in order to process the information or data obtained from the detectors during the measurements.

Preferably, the information obtained at the measurements of the dose distribution in the phantom is used at IMRT treatment verification.

Moreover, the overall measurement accuracy can be further improved by dividing the measurement in time-intervals. This also enabling use of individual correction factors for each time interval. In addition, this facilitates an evaluation of discrepancies in dynamic fields and/or ARC-therapy.

The length of a time interval depends on the IMRT technique used as well as the size and change of the correction factors. Thus, the time intervals are, i.a. defined from the required overall accuracy in dose determination. The dose contribution in each time interval can be totalised for the whole treatment as a first step to verify the complete treatment delivery, discrepancies can then be further analysed by comparisons at each field (projection) and sub fields.

According to preferred embodiments of the present invention, the correction factors are calculated according to

$$Corr_{n,\,f,\,seg\text{-}n,f,\,p,\,t(i),\,t(i+1)} = C_{dir} * C_{depth} * C_{pos} \qquad (1)$$

or

$$Corr_{n,\,f,\,seg\text{-}n,f,\,p,\,t(i),\,t(i+1)} = C_{dir} + C_{depth} + C_{pos} \qquad (2)$$

$Corr_{n,\,f,\,seg\text{-}n,f,\,p,\,t(i),\,t(i+1)}$ The correction factor to be used with detector-element n, in the sub-field, f in the phantom, correcting the measured dose integrated from time t(i) until t(i+1) to achieve the dose in the point of the detector n location.

C_{dir} Factor correcting for any directional dependency in the detector

C_{depth} Factor correcting for any depth (energy and or dose rate) dependency in the detector

C_{pos} Factor correcting for any position (in primary beam, outside primary beam, edge of primary beam etc.) dependency in the detector

According to embodiments of the present invention, each detector plane may be provided with detectors having a thickness in a range less than the range of the electrons of the maximum energy in the range where the dependency is significant. Thereby, the energy and/or directional dependency of the detectors are reduced significantly, which mainly is caused by differences in the photons mass-attenuation in the detectors compared with the media they are arranged in. Since the gantry is rotated about the phantom during the measurements, see fig. 1, the incident angle of the direction of the irradiation beams will vary considerably at the detectors of a detector plane and, hence, the accuracy and efficiency of the measurements can be enhanced significantly by reducing the directional dependency of the detectors. The directional dependency is a geometrical effect in the detector material and if it differs from the surrounding material, the irradiation beams will be affected, for example, at the transition between the surrounding material and the detector material. By making the detector uniformly shaped (spare) and/or as small as possible the directional dependency can be considerably reduced.

As realized by the person skilled in the art, the method of the present invention, as well as preferred embodiments thereof, are suitable to realize or implement as a computer program or a computer readable medium, preferably within the contents of the control and measurement system of the radiotherapy device, and thereby using the processor and storage means available there. Alternatively it may be implemented in a

stand-alone unit comprising the necessary equipment such as a central processing unit CPU performing the steps of the method according to the invention. This is performed with the aid of a dedicated computer program, which is stored in the program memory. It is to be understood that the computer program may also be run on a general purpose industrial computer instead of a specially adapted computer.

Further objects and advantages of the invention will be discussed below by means of exemplifying embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed description, reference will be made to the accompanying drawings, of which

Fig. 1a schematically shows a treatment machine to which a phantom is arranged, which in turn is provided with detectors,

Fig. 1b schematically shows the arrangement of Fig. 1a but with a human body instead of the phantom,

Fig. 2. schematically shows a typical example on a body shaped phantom with two crossing planes with detectors in a special arrangement to optimise the number of detectors.

Fig. 3. schematically shows various beam directions (projections) towards the body shaped phantom.

Figs. 4a-4c. schematically shows different examples of patterns for arranging the detectors on the detector planes.

Fig. 5 schematically shows an embodiment of the method of measuring dose distribution in a phantom for radiation therapy treatment verification according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A radiotherapy device (gantry) utilised for treating tumours with radiation are shown schematically in Figs. 1a and 1b and is generally denoted with reference numeral 10. The device comprises a radiotherapy system capable of emitting a beam 12 of electrons or photons from a treatment head. The radiotherapy system is provided with conventional field-shaping device (not shown), for example an MLC, for allowing the lateral shape of the beam to be altered so as to shield off non-affected areas of the body, intensity modulate the beam and concentrate the beam to the tumour. The radiotherapy system comprises control and measurement means (not shown) including processor and storage means, for example, a central processing unit CPU for performing the steps of the method according to the invention.

A treatment couch 16 is arranged for a patient 14 to lie on, see Fig. 1b. The couch can rotate around a vertical axis, and move horizontally, vertically and longitudinally in order to place the area to be treated of the patient in the area of the beam.

Further, the method according to the invention utilises detectors placed inside a phantom e.g. body-phantom in a way that reduces the required number of detectors to a minimum and still enables verification of the intensity modulated beams in all projections and simultaneously measures total dose distribution from all beam-projections in fixed points in the treated volume.

Preferably, the detectors are arranged in two or more non-parallel planes arranged in such a way that the crossing point of the planes is located in the vicinity of the rotation point of the treatment machine, preferably within 5 cm from the rotation point, and that either of the detector-planes covers the whole cross section of the beam in any projection figs. 2 and 3. Fig. 2 shows detector-planes 20 and 21 placed

inside the phantom 22 with detectors configured in lines 23 and in an area 24 and fig 3 is an illustration of typical beam directions 30 irradiating the phantom from different projections.

Figs. 4a-4c schematically shows different examples of detector patterns on detector planes 40, 40' and 40", respectively. Fig. 4a shows a detector plane 40 provided with a number of detectors lines 41, each line 41 represents an one dimensional (1D) array 42 of detectors 44 or a zigzag pattern 43 of detectors 44, Fig. 4b shows a detector plane 40' provided with detectors 44 arranged according to a two dimensional array, i.e. a matrix of detectors 44, and Fig. 4c shows a detector plane 40" provided with detectors 44 arranged according to combination of the configurations shown in figs. 4a and 4b.

The method according to the present invention is aimed to utilise the above-mentioned equipment in order to enable measurement and verification of dose delivery in radiotherapy treatment, in particular prior to applying the treatment on the patient (pre treatment verification). The measured dose distribution is aimed to be compared with the dose distribution from the planned treatment of the specific patient after recalculating it to a similar phantom as the measurement phantom.

A typical sequence from diagnostics to IMRT treatment are described below:

- An individual treatment plan for the patient is made using a Treatment Planning System (TPS). The anatomy of the patient has first been defined using diagnostic equipment e.g. CT, Computerised Tomography and the radiation characteristics of the treatment device is defined generally by measurements both imported in the TPS. The target-volume and risk-organs are defined and then the optimum plan for the treatment is made where criteria as maximum dose to the risk-organs and the

minimum dose to the target etc. is used. The outcome of the plan is information that will be used by the treatment machine to set projections, beam modality, field shapes and movement of the MLC-leaves etc.

- The patient specific treatment plan, in the TPS, is applied on a phantom, suitable for dose measurements, and the dose distribution inside the phantom, using the patient specific treatment, is calculated.
- Prior to treatment, a physical phantom, identical to the one simulated in the calculation, is irradiated using the patient specific treatment. The dose distribution inside the phantom is measured and integrated per projection and for all projections, complete fraction.
- The measured and the calculated dose distribution are compared to verify the delivery of the patient specific treatment.

Accordingly, information regarding the dose distribution inside said phantom is obtained by performing measurements using the detectors, which information is used in the treatment verification and/or stored.

Turning now to fig. 5, the method of measuring dose distribution in a phantom for radiation therapy treatment verification according to the present invention will be described in more detail. First, at step 51, the detectors are arranged on the detector planes in the phantom according to a detector pattern, for example, one of the patterns shown in one of figs 4a-4c. The phantom including the detectors is placed in the isocenter (rotation centre) of the treatment machine and is aligned using the positioning lasers in the treatment room. The measurements electronics is connected to a PC located in the control room. A connection between the treatment machine and the measurements electronics and/or via a LAN to the controlling PC might be established to synchronize the measurement and the delivery of the treatment. Subsequently, at step 52, the patient specific treatment is given, i.e. the

phantom is irradiated according to the specific treatment. Then, at step 53, the measurement data from each detector is collected for each time-interval. By dividing the measurement in time-intervals and using individual correction factors for each time-interval, a further enhancement of the measurement accuracy can be accomplished, see below. At step 54, after completed irradiation, or simultaneously, the data is processed and corrected using equations (1) or (2). Thereafter, at step 55, the total dose delivered to each detector is calculated. Further, the planed treatment is imported to the PC-SW. Then, at step 56, the measured dose is compared with the calculated dose. If the deviation exceed a certain action-level, the calculated dose distribution in the treatment plan in each projection might be imported and the dose is recalculated for each projection for comparison. If it is required, the comparison can be performed on sub-fields (i.e. a part of a projection).

As indicated above, a further enhancement of the measurement accuracy can be accomplished by dividing the measurements in time-intervals and using individual correction factors for each time-interval. The length of a time interval depends on the IMRT technique used as well as the size and change of the correction factors. Thus, the time intervals are i.a. defined from the required overall accuracy in the dose determination. The dose contribution in each time interval can be totalised for the whole treatment as a first step to verify the complete treatment delivery, discrepancies can then be further analysed by comparisons at each field (projection) and sub fields. According to preferred embodiments of the present invention, the correction factors are calculated according to

$$Corr_{n,\,f,\,seg\text{-}n,f,\,p,\,t(i),\,t(i+1)} = C_{dir} * C_{depth} * C_{pos} \qquad (1)$$

or

$$Corr_{n,\,f,\,seg\text{-}n,f,\,p,\,t(i),\,t(i+1)} = C_{dir} + C_{depth} + C_{pos} \qquad (2)$$

$Corr_{n, f, seg\text{-}n,f, p, t(i), t(i+1)}$ The correction factor to be used with detector-element n, in the sub-field, f in the phantom, correcting the measured dose integrated from time t(i) until t(i+1) to achieve the dose in the point of the detector n location.

C_{dir} Factor correcting for any directional dependency in the detector

C_{depth} Factor correcting for any depth (energy and or dose rate) dependency in the detector

C_{pos} Factor correcting for any position (in primary beam, outside primary beam, edge of primary beam etc.) dependency in the detector

Which one of (1) or (2) that is selected depends on how C_{dir}, C_{depth} and C_{pos} were obtained. Preferably, equation (1) is used when the correction factors are accepted to be independent of each other and, accordingly, can be obtained individually. Obtaining the correction factors using this equation is time efficient. Preferably, equation (2) is used if each combination of factors are to be measured. This method provides very accurate results.

The detectors used might be of various types e.g. semiconductors, gas detectors, scintillators etc. If the detector-material differs in mass-density or electron-density from the phantom it might be selected thin at least in one dimension to reduce energy and directional dependency. Preferably, the detector is made thinner than the range of the electrons of the maximum energy in the range where the dependency is significant, e.g. for Si-detector in water the energy dependency is documented for photons with energy less than 200keV where the electron range in Si is 200 um. The directional dependency is improved when Silicon is thinner than 500 um.

- For a detector where all material except the sensitive part, is similar in mass-attenuation as the media it will measure in, only the sensitive part have to be thinner than the range of the electrons, for the maximum energy where the dependency is significant, in order to reduce the energy dependency
- For a detector where both the sensitive part and the surrounding material differ in mass-attenuation compared to the media it is arranged in, the sensitive part and the material that differs must be thin enough to reduce the energy dependency.

In addition, the "thin detector", i.e. a detector having a thickness made thinner than the range of the electrons of the maximum energy in the range where the dependency is significant, can preferably be used in several other applications such as: Water phantom dosimetry and in vivo dosimetry during Brachy therapy in Radio therapy. Water phantom dosimetry is performed using fixed detectors or detectors placed on a servo mechanism in a phantom filled with water. The system has several applications: acceptance tests of a treatment machine – general measurement of the dose distribution from the treatment machine; and measurement of the dose distribution in 3D. In vivo dosimetry during Brachy therapy (radioactive sources inserted into the human body) incorporates measurements inside the human body, interstitial or intra cavity e.g. thrachea, uterus, rectum, and bladder

The method according to the invention may be implemented in the control and measurement system of the radiotherapy device, and thereby using the processor and storage means available there. Alternatively it may be implemented in a stand-alone unit comprising the necessary equipment such as a central processing unit CPU performing the steps of the method according to the invention. This is performed with the aid of a dedicated computer program, which is stored in the program memory. It is to be understood that the computer

program may also be run on a general purpose industrial computer instead of a specially adapted computer.

The software includes computer program code elements or software code portions that make the computer perform the method using equations, algorithms, data and calculations previously described. A part of the program may be stored in a processor as above, but also in a ROM, RAM, PROM or EPROM chip or similar. The program in part or in whole may also be stored on, or in, other suitable computer readable medium such as a magnetic disk, CD-ROM or DVD disk, hard disk, magneto-optical memory storage means, in volatile memory, in flash memory, as firmware, or stored on a data server.

It is to be understood that the above description of the invention and the accompanying drawings is to be regarded as a non-limiting example thereof and that the scope of protection is defined by the appended patent claims.

PATENT CLAIMS

1. Method of measuring dose distribution in a phantom for radiation therapy treatment verification, c h a r a c t e r i s e d in that it comprises the steps of

arranging at least two detector planes in said phantom in a non-parallel manner, each plane being provided with a plurality of detectors;

irradiating said phantom using a patient specific treatment;

obtaining information regarding the dose distribution inside said phantom by performing measurements using said detectors, wherein said information is to be used in the treatment verification.

2. Method of configuration detectors in a phantom at measurements of dose distribution at radiation therapy treatment verification, c h a r a c t e r i s e d in that it comprises the steps of

arranging at least two detector planes in said phantom in a non-parallel manner, each plane being provided with a plurality of detectors.

3. Method according to claim 1 or 2, wherein the information obtained by means of said measurements is used for IMRT verification.

4. Method according to claim 1, 2 or 3, wherein said phantom is fixed relatively to the gantry rotation, c h a r a c t e r i s e d in that it further comprises the step of

arranging said detector planes such that, for each gantry angel projection, either of said non-parallel planes intersects with all parts of the radiation beam or sub-beams.

5. Method according to claim 1, 3 or 4, wherein the step of obtaining information comprises the steps of

dividing the measurements in time-intervals.

6. Method according to 5, c h a r a c t e r i s e d in the further step of

calculating correction factors for each time-interval using said obtained information regarding the dose distribution inside said phantom.

7. Method according to any one of claims 1, 3-5, c h a r a c t e r i s e d in the further step of

storing the data for each specific time-interval for measurements in said phantom.

8. Method according to claim 6 or 7, c h a r a c t e r i s e d in that the correction factors are calculated according to

$Corr_{n,\,f,\,seg\text{-}n,\,p,\,t(i),\,t(i+1)} = C_{dir} * C_{depth} * C_{pos}$

where

$Corr_{n,\,f,\,seg\text{-}n,\,p,\,t(i),\,t(i+1)}$	The correction factor to be used with detector element n, in the sub field f in the phantom, correcting the measured dose integrated from time t(i) until t(i+1) to achieve the dose in the point of location of detector n
C_{dir}	Factor correcting for any directional dependence in detector n
C_{depth}	Factor correcting for any depth (energy and/or dose rate) in detector n
C_{pos}	Factor correcting for any position (in primary beam, outside primary beam,

edge of primary beam, etc.) dependency in detector n.

9. Method according to claim 6 or 7, c h a r a c t e r i s e d in that the correction factors are calculated according to

$Corr_{n, f, seg\text{-}n, p, t(i), t(i+1)} = C_{dir} + C_{depth} + C_{pos}$

where

$Corr_{n, f, seg\text{-}n, p, t(i), t(i+1)}$	The correction factor to be used with detector element n, in the sub field f in the phantom, correcting the measured dose integrated from time t(i) until t(i+1) to achieve the dose in the point of location of detector n
C_{dir}	Factor correcting for any directional dependence in detector n
C_{depth}	Factor correcting for any depth (energy and/or dose rate) in detector n
C_{pos}	Factor correcting for any position (in primary beam, outside primary beam, edge of primary beam, etc.) dependency in detector n.

10. Method according to any of the preceding claims, wherein said detectors are arranged according to a predetermined pattern.

11. Method according to any of the preceding claims, wherein said planes are planispherically shaped.

12. Method according to any one of the preceding claims, c h a r a c t e r i s e d in the further step of

providing each detector plane with detectors having a thickness in a range less than the range of the electrons of the maximum energy in the range where the dependency is significant.

13. Detector configuration in a phantom suitable for radiation therapy, c h a r a c t e r i s e d by at least two detector planes provided with a plurality of detectors for measuring irradiation in said phantom, said planes being arranged in a non-parallel manner.

14. Detector configuration according to claim 13, wherein said detector configuration is arranged for measurements of dose distribution in said phantom for IMRT verification.

15. Detector configuration according to claim 13 or 14, wherein said phantom is fixed relatively to the gantry rotation, c h a r a c t e r i s e d in that said non-parallel planes are arranged such that, for each gantry angel projection, either of said planes intersects with all parts of the radiation beam or sub-beams.

16. Detector configuration according to claim 13, 14 or 15, wherein said detectors are arranged according to a predetermined pattern.

17. Detector configuration according to any of the claims 13-16, wherein said planes are planispherically shaped.

18. Detector configuration according to any of the claims 13-17, wherein said detectors has a thickness in a range less than the range of the electrons of the maximum energy in the range where the dependency is significant.

19. Computer readable medium comprising instructions for bringing a computer to perform a method according to any one of the claims 1 or 3-12.

ABSTRACT

The present invention relates to a method to measure dose distribution in a patient-shaped phantom with high accuracy. The invention consists of a method of measuring dose distribution in a phantom for radiation therapy treatment verification, a detector configuration in such a phantom, detector improvement and measurement methodology to enable application of correction factors in an accurate way.

(Fig. 1)

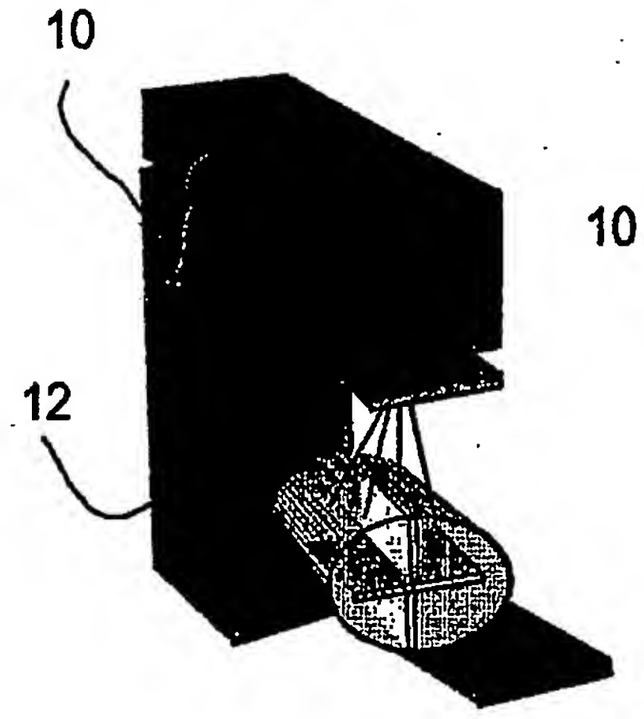

Fig. 1a

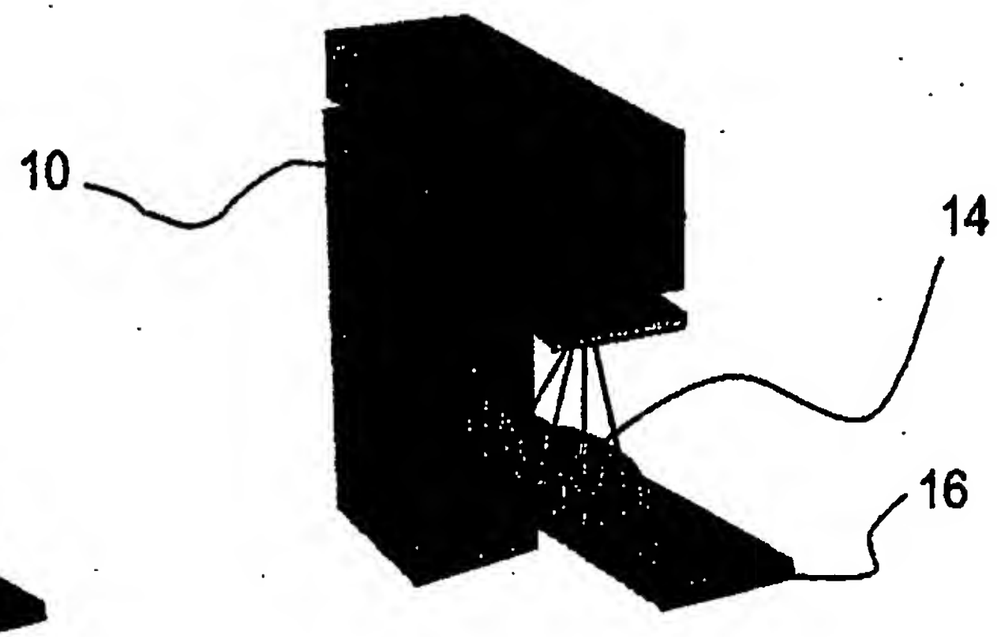

Fig. 1b

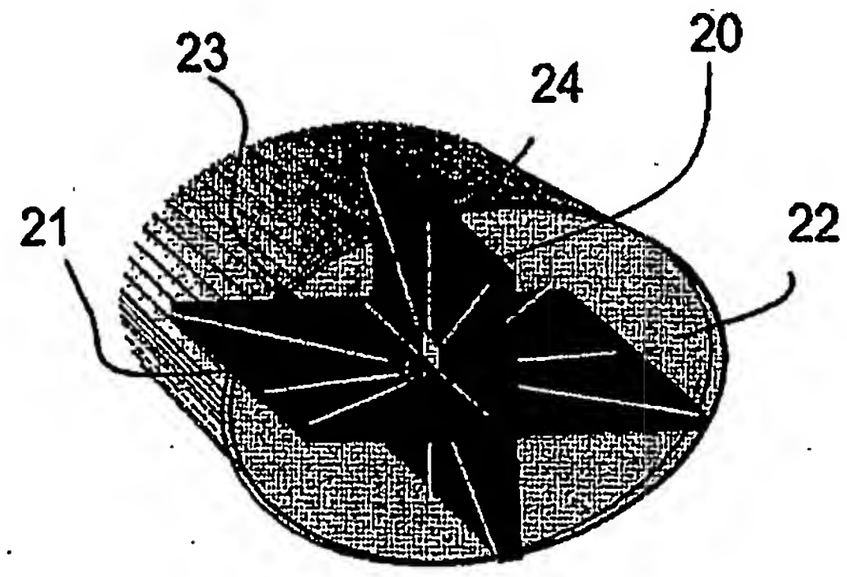

Fig. 2

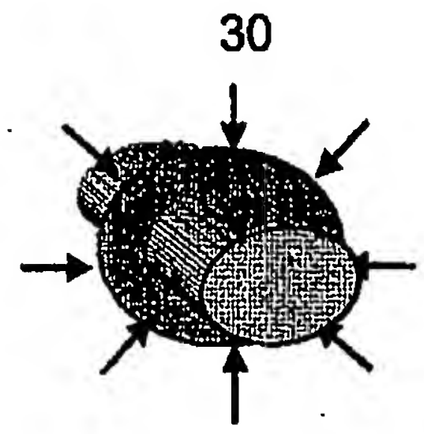

Fig. 3

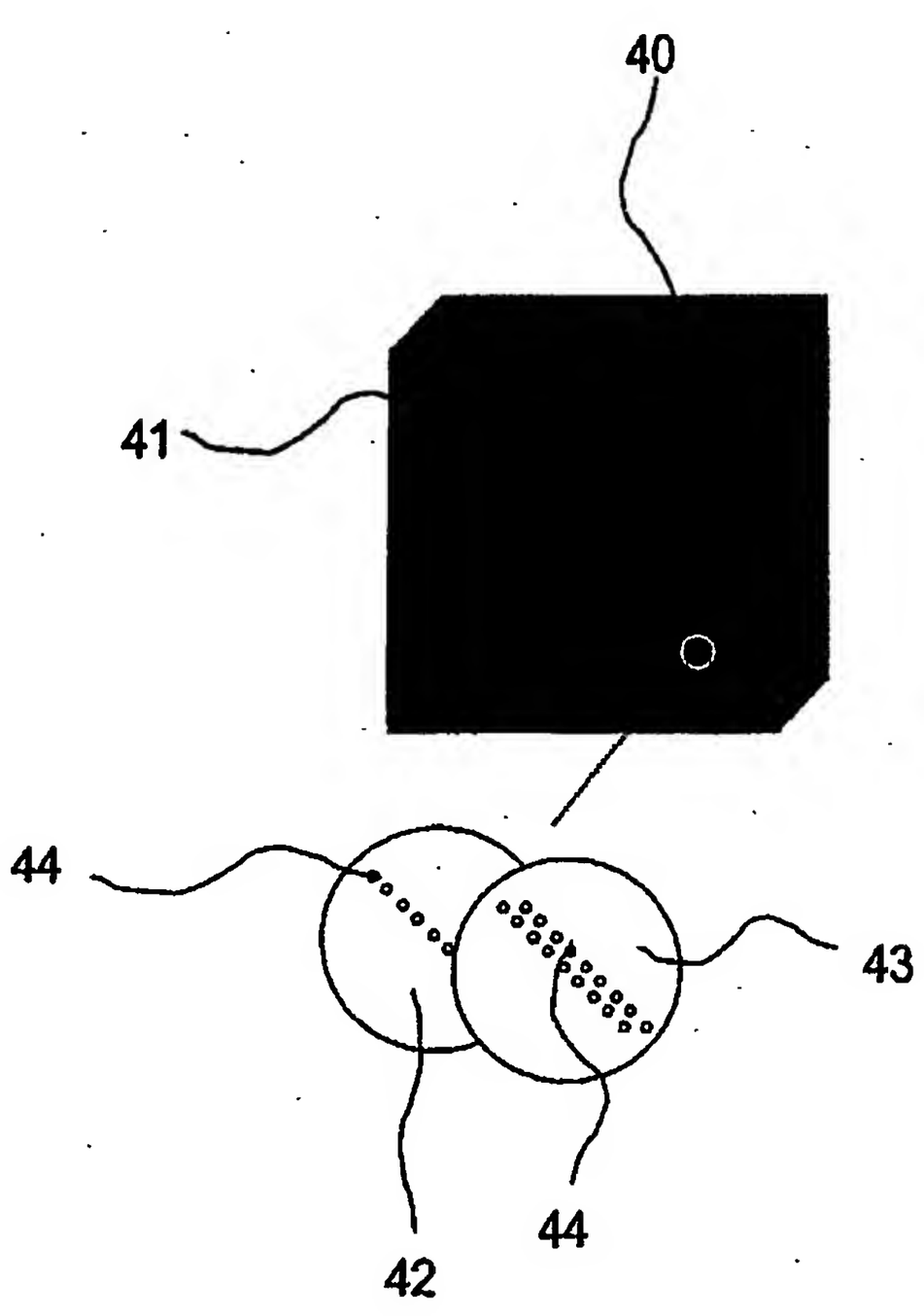

Fig. 4a

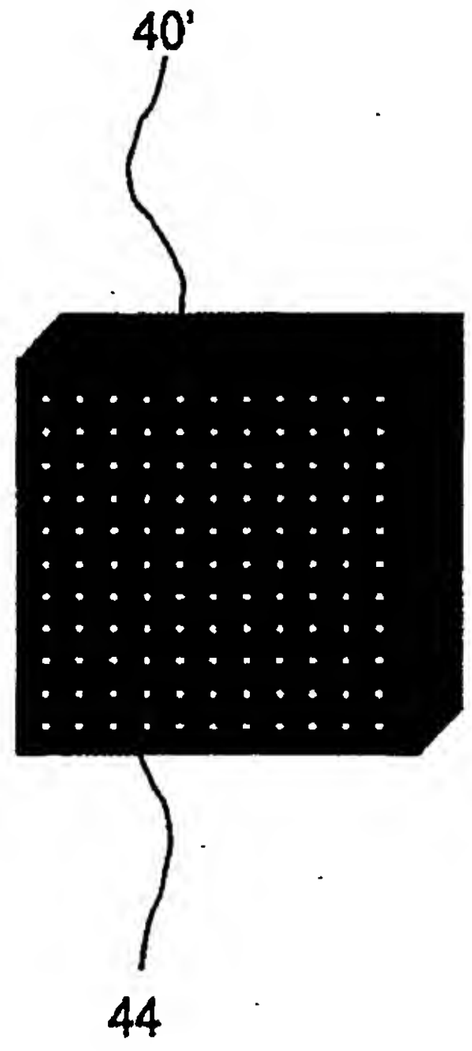

Fig. 4b

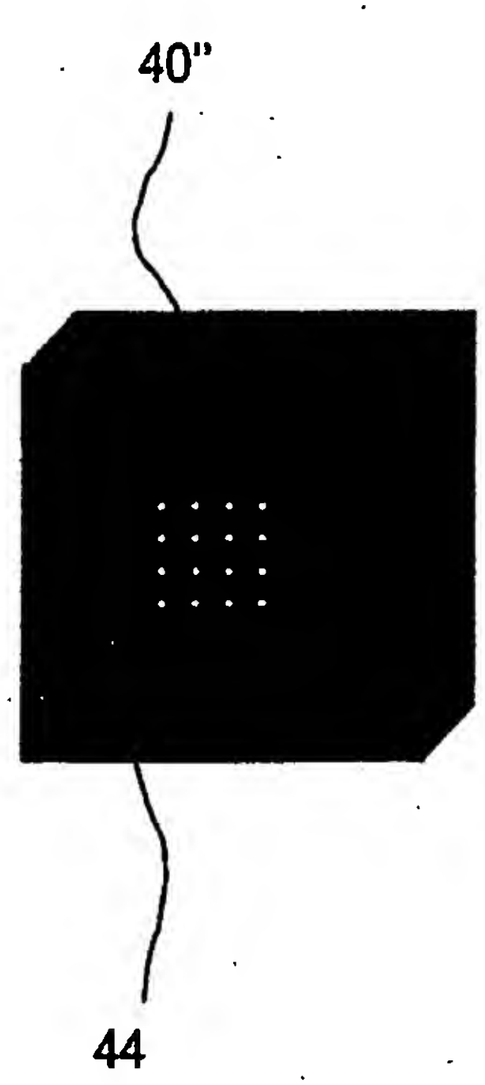

Fig. 4c

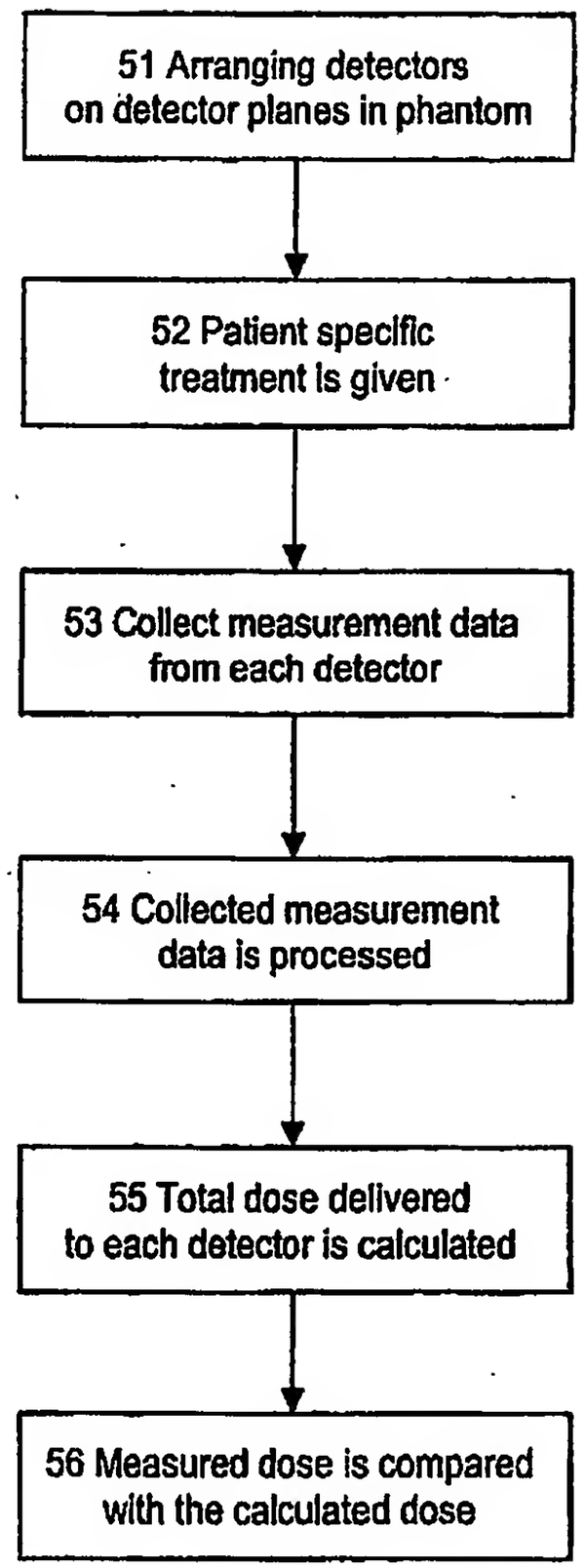
51 Arranging detectors on detector planes in phantom
52 Patient specific treatment is given
53 Collect measurement data from each detector
54 Collected measurement data is processed
55 Total dose delivered to each detector is calculated
56 Measured dose is compared with the calculated dose

Fig. 5